

CLINICAL GOVERNANCE

UPDATED ANS/BSCN GUIDELINES FOR NEUROPHYSIOLOGICAL RECORDINGS OF THE SPINAL CORD DURING CORRECTIVE SPINAL DEFORMITY SURGERY

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This document, from the joint national audit panel British Society of Clinical Neurophysiology (BSCN) and Association of Neurophysiological Scientists (ANS), presents updated and revised guidelines for Neurophysiological recordings of the spinal cord during corrective spinal deformity surgery.

The revised guidelines have been produced for intra-operative Neurophysiological monitoring (IONM) following the national audit and survey in 2016. The guidelines supersede, revise and re-organise the previous guidelines, published in 2013. The main changes from the previous version are to upgrade from guideline to standard the recording of transcranial muscle motor evoked potentials (MEP), including upper limb controls. The inclusion of a peripheral nerve recording as a technical control during sensory evoked potential recording (SEP) is also changed from a guideline to a standard. Additional changes to the layout have been made.

This document seeks to recommend guidelines which are evidence based, relevant to current and future practice, auditable and in a comprehensive form that is achievable. IONM should be carried out by competent medical and physiological staff trained in this speciality. This document is aimed to support people in their clinical practice and is not intended to exclude existing protocols and procedures in departments depending on local practice and resources. These guidelines are subject to change and will be regularly reviewed

In all cases it is the responsibility of the operating spinal surgeon and team to establish the indication and appropriateness for IONM

PRACTICE and DETAIL

Three levels of practice are identified:

- 1) Standards – represent the minimum that must be achieved in all cases
- 2) Guidelines – suggestions that may be helpful in some clinical circumstances
- 3) Practice – the practical application of the standard/guideline

General Principles

Standard 1:

Prior to surgery the patient is identified, the clinical information is verified and the need for IONM is assessed.

Standard 2:

During surgery the evoked potential waveforms are identified, their repeatability is assessed and the responses are monitored against a reference waveform throughout the surgical

procedure.

Practice:

A reference waveform should be obtained before commencement of any spinal surgery or instrumentation. Monitoring should continue for at least 20 minutes after completing instrumented fixation, or until monitoring is no longer possible.

Standard 3:

Waveforms should be identifiable with respect to both stimulation and recording sites used, including documentation of upper/lower limb and left/right side (as appropriate).

Standard 4:

A predetermined warning criterion is established that defines a significant repeatable change in a waveform that cannot be explained by reversible technical or anaesthetic changes (see below for modality specific warning criteria).

Standard 5:

The latency and amplitude of the waveforms are labelled where possible, and are compared to the reference waveform or, if appropriate, a preceding value.

Guideline:

Responses are accurately timed in relation to theatre clocks to enable comparable timing of surgical/anaesthetic events.

Standard 6:

During multimodal IONM SEP and MEP should be repeatedly recorded throughout the procedure.

Practice:

Averaged SEP recordings should be interleaved with MEP recording where possible throughout the procedure (and should be near continuous during key points of surgery, e.g. during corrective manoeuvres).

Standard 7:

The operating team is alerted to a significant change in the waveforms in a timely manner.

Standard 8:

A clear, concise and accurate record of the annotated waveforms should be kept. Any information conveyed to the surgeon and/or anaesthetist, and any response/action or outcome should be recorded/annotated.

Practice:

Data collection and storage will vary for different departments and equipment. If possible, all original data should be stored electronically, available for review at the time of reporting, and archived (with appropriate backup). Archiving patient information needs to be in keeping with hospital policies.

Standard 9:

Annotations in the record must include:

Patient name

Patient date of birth

Patient hospital or NHS number/IONM identifier

Date of operation

Surgical procedure (e.g. anterior/posterior fixation)

Name of the consultant surgeon(s) performing surgery

Name of the consultant anaesthetist

Name of person(s) performing the monitoring

Protocol used/changes to protocol
Technical problems/changes

Details of any IONM alerts and responses to those alerts.

Intraoperative Lower limb Somatosensory Evoked Potentials (LLSEPs)

Standard 10:

Lower limb sensory evoked potentials are recorded following stimulation of a nerve below the site of the surgery, and recordings made above the site of the surgery.

Practice:

Stimulation of the tibial nerve at supramaximal intensity below the site of surgery. Bilateral independent peripheral nerve stimulation is advised.

Standard 11

Control Upper Limb SEPs should be recorded. Following stimulation of an upper limb nerve the evoked potentials are recorded above the site of the surgery to help better distinguish technical and systemic changes from significant changes in spinal cord function related to the surgery.

Practice:

Stimulation of the median or ulnar nerve at the wrist, elbow/antecubital fossa (ACF). Bilateral independent peripheral nerve stimulation is advised.

Standard 12

Whenever possible, control Peripheral SEPs should be recorded. Sensory nerves may be stimulated and the evoked potentials recorded from a peripheral recording site.

Practice:

LLSEP: Stimulation of the tibial nerve at ankle, with recording at the popliteal fossae.

ULSEP: Stimulation of the median/ulnar nerve at wrist, with recording at the cubital fossae and/or Erb's point. This will help better distinguish technical changes and arm positional changes.

Standard 13:

A predetermined SEP warning criterion is established that defines a significant repeatable change in amplitude and/or latency of the waveform that cannot be explained by reversible technical or anaesthetic changes.

Common SEP alert criteria include:

Disappearance of waveform

Amplitude reduction (50% or more)

Latency increase (10% or more)

Any change that cannot be explained technically or anaesthetically

Intraoperative Motor Evoked Potentials (MEPs)

Standard 14.

Whenever possible the corticospinal pathways of the spinal cord are monitored using Motor Evoked Potentials across the site of surgery, i.e. if there are no contraindications. There are relative contraindications for the use of transcranial electrical stimulation in the published

literature (MacDonald, 2002), but absolute contraindications are now considered to be few (MacDonald et al., 2013).

Guideline 14a:

MEPs should be recorded when possible in the absence of any neuromuscular blockade agents and utilising an appropriate anaesthetic regime.

Practice:

Short acting neuromuscular blockade is often used to aid intubation of the patient during induction of anaesthesia. A 'train of four response' after peripheral nerve stimulation (e.g. posterior tibial nerve at the ankle, recording from Abductor Hallucis muscle) can be used to check that the effect of the neuromuscular blockade agent has worn off. The most appropriate anaesthetic regime should be determined locally, but use of Total Intravenous Anaesthesia (TIVA) is recommended in the literature (MacDonald et al., 2013)

Standard 15

MEPs require stimulation of a neural structure above the site of the surgery with responses recorded below the site of surgery

Practice:

Stimulation via electrodes placed on the scalp over the motor cortex area. Optimising the MEP stimulus parameters is recommended (MacDonald et al., 2013). Bilateral recording from 2 or more muscles on each leg is indicated. Common sites include: tibialis anterior and abductor hallucis but other muscles recording sites may be required depending upon the type and level of surgery.

It is advised that a bite block be used to reduce the likelihood of a bite injury.

Precautions should be taken to minimise the risk of movement induced injury (reduce patient movement by optimisation of MEP stimulus parameters and electrode positioning; communication with surgical staff; use of camera to visualise the surgical field).

Standard 16:

The recording of control upper limb MEPs

MEPs may be recorded above the site of the surgery to help better distinguish technical and systemic* changes from significant** changes in spinal cord function related to the surgery.

Practice:

Bilateral recording from muscles is indicated. Common sites for muscles above the site of surgery include small hand muscles. Forearm flexors, forearm extensors, deltoids etc. may also be used, depending upon the type and level of surgery.

Standard 17:

A predetermined MEP warning criterion is established that includes a repeatable significant change of the waveform that cannot be explained by reversible technical or systemic causes*.

Practice:

For spinal cord monitoring disappearance of the MEP is a major alert criterion. Other criteria may be appropriate depending upon the variability of the waveforms preceding the change (MacDonald et al., 2013). These moderate criteria may include abrupt amplitude reduction by 80%. Abrupt threshold elevation (>100V) may be a valid criterion, but only when used with the methodology of the author of the paper citing this criterion is utilised (Calancie, 2017; MacDonald, 2017).

Note muscle MEP responses are inherently variable and can even disappear due to systemic causes*. It is very important the monitoring staff have the expertise to recognise and reverse these changes. A gradual reduction in MEP responses is common ('MEP fade, MacDonald et al., 2013) requiring increased MEP stimulation and/or lightening of the anaesthetic level to reverse the change. Systemic changes can be more readily identified when MEPs are being recorded at frequent intervals.

* Systemic causes include anaesthetic changes, temperature, blood pressure, hypovolemia etc.

APPENDIX 1.

Rationale and evidence base

There are experimental reasons why monitoring of sensory and motor pathways during corrective spinal surgery may provide warning of impending neural injury at a reversible stage, presumably due to mechanical stress causing ischaemia of neural tissue (*Seyal and Mull, 2002*), and thereby providing a theoretical window of opportunity for therapeutic intervention. The landmark multicentre survey of Nuwer and colleagues (*1995*), capturing 51,263 monitored cases in 97,585 surgeries, suggested that somatosensory evoked potential monitoring helped to significantly reduce neurological deficits after scoliosis surgery (Chi-square = 10.8, $p \leq 0.01$). However, experience has taught us that some patients still develop neurological deficits, even in spite of unchanged somatosensory evoked potentials (*Lesser et al., 1986*), making an argument for monitoring of the cortico-spinal motor pathways (*Deletis and Sala, 2008*). Conversely, only a proportion of patients (16% to 40%) who do demonstrate important changes in their somatosensory and/or motor evoked potentials will develop paraparesis, paraplegia or quadriplegia (*Nuwer et al., 2012*). Recent data from the Scoliosis Research Society (SRS) appears to have shown a disappointing sensitivity for both somatosensory and motor evoked potentials of only 43%, and lack of standardisation may be a contributing factor, although it is noted that the SRS report lacks enough detail about the IONM in these reported cases and this figure is disputed (*Eccher, 2012*).

Clearly neurophysiological monitoring does not have a perfect predictive ability, with its trade-off between sensitivity and specificity, and this limitation means we should not assume that it safeguards the spinal cord. However, significant motor deficits are so devastating for patients that we are duty bound to maintain our efforts to improve safety of patient care for those undergoing spinal surgery; by continuing to develop good medical practice through implementing guidelines, research and audit in the field of neurophysiological monitoring.

At the time of publication of the first version of these guidelines, combined SEP and MEP recording were increasingly being utilised and recommended internationally (*Sutter et al., 2007*). Further evidence based guidelines have been published in recent years to support inclusion of MEPs as part of a multi-modal monitoring approach to IONM (*MacDonald et al., 2013; Leggatt et al., 2016*). Furthermore the BSCN/ANS IONM survey showed that, when there are no contraindications, MEP monitoring was universally utilised for monitoring scoliosis surgery. As a result, in this version of the guidelines, the recording of MEPs has been upgraded from a guideline to a standard in all cases where MEPs are not otherwise contraindicated.

The 2013 American Society of Neuromonitoring (ASNM) guidelines for MEP monitoring (*MacDonald et al., 2013*) give a detailed discussion of the MEP alert criteria, stimulation parameters and updated evaluation of the risks of transcranial electrical stimulation of the brain. Some of the previously mentioned MEP alert criteria (e.g. morphology and latency changes in MEP) and contraindications are no longer thought to be valid (*Macdonald, 2017*) and have subsequently been removed from these updated guidelines. D waves are not indicated for IONM during spinal corrective surgery (*Ulkatan, 2006; MacDonald, 2013*) and so mention of this technique in this context has been removed.

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References

- Calancie, B. (2017)** Intraoperative neuromonitoring and alarm criteria for judging MEP responses to transcranial electric stimulation: The threshold-level method. Invited review, *J Clin Neurophysiol*;34:12–21).
- Deletis, V., Sala, F. (2008)** Intraoperative Neurophysiological monitoring of the spinal cord during spinal cord and spine surgery: a review focussed on the corticospinal tracts. *Clin Neurophysiol*; 119:248-264.
- Eccher, M. (2012)** Intraoperative Neurophysiological monitoring: are we really that bad? *J Clin Neurophysiol*; 29: 157-159.
- Lesser, R.P., Raudzens, P., Luders, H., Nuwer, M.R., Goldie, W.D., Morris, H.H., Dinner, D.S., Klem, G., Hahn, J.F., Shetter, A.G., Ginsburg, H.H., Gurd, A.R. (1986)** Postoperative neurological deficits may occur despite unchanged intraoperative somatosensory evoked potentials. *Ann Neurol*;19: 22-25.
- Legatt, A.D., Emerson, R.G., Epstein, C.M., MacDonald, D.B., Deletis, V., Bravo, R.J., and López, J.R. (2016)** ACNS Guideline: Transcranial Electrical Stimulation Motor Evoked Potential Monitoring. *J Clin Neurophysiol*. 33: 42–50).
- MacDonald, D.B. (2002)** Safety of intraoperative transcranial electrical stimulation motor evoked potential monitoring. *J Clin Neurophysiol*;19:416-29.
- Nuwer, M.R., Dawson, E.G., Carlson, L.G., Kanim, L.E.A., Sherman, J.E. (1995)** Somatosensory evoked potentials spinal cord monitoring reduces neurological deficits after scoliosis surgery: results of a large multicenter survey. *Electroencephalogr Clin Neurophysiol*; 96: 6-11.
- MacDonald, D.B., Skinner, S., Shils, J., Yingling, C. (2013)** Intraoperative motor evoked potential monitoring a position statement by the American Society of Neurophysiological Monitoring. *Clin Neurophysiol*;124:2291–2316.
- MacDonald, D.B. (2017)** Overview on criteria for MEP monitoring. *J Clin Neurophysiol*;34: 4–11).
- Nuwer, M.R., Emerson, R.G., Galloway, G., Leggatt, A.D., Lopez, J., Minahan, R., Yamada, T., Goodin, D.S., Armon, C., Chaudhry, V., Gronseth, G.S., Harden, C.L. (2012)** Evidence-based guideline update: Intraoperative spinal monitoring with somatosensory and transcranial electrical motor evoked potentials. *Neurology*;78: 585-589.
- Seyal, M., Mull, B. (2002)** Mechanisms of signal change during intraoperative somatosensory evoked potential monitoring of the spinal cord. *J Clin Neurophysiol*;19: 409-415.
- Sutter, M., Deletis, V., Dvorak, E., Eggspueller, A., Grob, D., MacDonald, D.B., Mueller, A., Sala, F., Tamaki, T. (2007)** Current opinions and recommendations on multimodal intraoperative monitoring during spine surgeries. *Eur Spine J*, 16(S2):S232-7
- Ulkatan, S., Neuwirth, M., Bitan, F., Minardi, C., Kokoszka, A., Deletis, V. (2006)** Monitoring of scoliosis surgery with epidurally recorded motor evoked potentials (D wave) revealed false results. *Clin Neurophysiol*;117:2093–2101.